Factors Affecting Characteristics, Composition, and Quality of Skimmilk Cheese

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Abstract

Results of a comprehensive study of factors affecting development of a skimmilk cheese are described. The study included variables relating to milk processing, cheese-making procedures, use of supplemental starters, milk treatment with animal and microbial enzymes, and the use of food additives, stabilizers, condiments, and flavor-enhancing substances. Flavor and texture of experimental cheeses were markedly affected by the amount of milk fat, moisture content, the activation of intrinsic milk lipases, and the rate and extent of acid development. The manufacturing procedures most directly related to control of moisture, acidity, and flavor were homogenization of milk fat, fortification of cheese milk with skimmilk solids, type and amount of starter, curd size, rate and extent of curd cooling, and the temperature and type of cheese pressing. The results show interrelated and compensating effects from simultaneous variations in two or more individual steps or procedures. Results of this study served as a basis for the previously described manufacturing procedure. Influences of supplemental starters, condiments, and flavor additives on the basic procedure are discussed.

Low-fat and skimmilk cheeses made by the conventional Cheddar cheese procedure are very hard, leathery, and unpalatable, even after extensive curing. In preliminary attempts to develop an improved skimmilk cheese, it was apparent that drastic changes in the conventional manufacturing procedures would be necessary. First, it appeared that the normal moisture content of skimmilk cheese (50% or less) was much too low to allow rapid ripening and softening of the body. Thus, in outlining a study to develop a method for making skimmilk cheese, considerable attention was given to those manufacturing procedures and variables which would allow greater moisture retention in the curd, namely: heat treatment of milk, homogenization of milk fat, setting temperature, curd size, cooking temperature, stirout time, and rate of cooling the curd. Whitehead and Harknes (9) have shown the effect of most of these manufacturing operations on moisture expulsion from the curd of Cheddar cheese. With the fat content of the cheese greatly reduced, it was also evident that special means of developing or incorporating flavor into the cheese would be necessary. Patton (5) has emphasized the importance of milk fat in flavor development in Cheddar cheese.

This paper describes the effects of various factors on the characteristics, composition, and quality of a new type of semisoft, ripened, low-fat cheese. The study included the following variables: milk processing, cheese-making procedures, use of various lactic and supplemental starter cultures, milk treatment with animal and microbial enzymes, and the use of food additives, stabilizers, condiments, and flavor-enhancing substances. Primary attention was directed to factors affecting body and texture, with secondary emphasis on flavor development. The manufacturing procedure described previously (3) was based on results of this study.

Experimental Procedure

Equipment. Equipment used in this study was the same as that described previously (3).

Milk processing. The milk was obtained from the Dairy Husbandry Research Branch, USDA, Beltsville, Maryland. Usually, the fresh whole milk was cold-separated and pasteurized by the HTST method (72.1 C—15 sec). In studies with under-pasteurized milk, a holding period of 5 min was used.

The skimmilk was standardized to contain varied amounts of milk fat (0.2 to 1%) by adding appropriate amounts of pasteurized cream or whole milk. The solids content of the cheese milk was varied by adding appropriate amounts of low-heat nonfat dry milk (NDM) or concentrated skimmilk to the fresh skimmilk.

In most homogenization studies, only the whole milk or cream, instead of the entire lot of standardized milk, was homogenized. Homogenization pressures from 1,000 to 6,000 lb psi were compared.

Manufacturing procedures. The amount of lactic starter used in cheese making was varied from 0.5 to 10%. The milk was usually ripened at 20–32 C for varied periods of time, ranging from 0 to 2 hr. In most studies, the milk was set with commercial rennet at the rate of 75 cc/454 kg of milk. The setting period was usually between 20 and 30 min at 32 C, depending

on amount of starter added and length of the ripening period. The curd was cut into cubes ranging from 6.4 to 15.8 mm. Cooking temperatures ranging from 34.4 to 47.7 C were compared. After draining the whey, the curd was stirred for varied periods, from 0 to 30 min.

In studies on curd cooling and washing, temperature of the wash water was varied from 0 to 37.7 C. The curd was pressed with weights ranging from 2 to 11.5 kg per hoop and at temperatures from 4.4 to 24 C.

Vacuum pressing for a short time (5–20 min) was compared with conventional pressing. Curing temperatures of 4.4 and 10 C were compared.

Starters. In addition to commercial mixed lactic starters, four other starters were used: mixed single strains of *Streptococcus lactis,* mixed single strains of *Streptococcus cremoris,* mixed single strains of *S. cremoris* containing 10–30% *Leuconostoc,* and mixed single strains of *S. cremoris* containing 10–30% *Streptococcus diacetylactis.* Bulk lactic starters were prepared in a conventional manner; that is, 1% of inoculum was added to steamed skimmilk and incubation was at 22.2 C for 16–18 hr. In some studies, whole milk starters and 24-48-hr starters were tested.

The species tested as supplemental starters in combination with the usual lactic cultures were: *Lactobacillus casei, Lactobacillus lactis, Lactobacillus plantarum, Pediococcus cerevisiae, Brevibacterium linens,* and several species of *Micrococcus* and *Pseudomonas.* They were added to the cheese milk as a 0.5% inoculum. However, in some instances they were used to pretreat the milk fat or whole milk.

Development of milk rancidity. In attempts to develop a mild rancidity in the cheese, four methods were compared: 1) direct addition of commercial pregastric esterases to the cheese milk, 2) addition of lipolytic microorganisms, 3) pretreatment of the milk fat to develop varying degrees of rancidity, and 4) direct addition of fatty acids to the milk.

Active commercial pregastric esterases were added to the cheese milk in amounts ranging from 1 to 3 g per 454 kg of milk. The lipolytic microorganisms were species of *Micrococcus* and *Pseudomonas.* Controlled rancidity was obtained by homogenizing raw whole milk or cream and inactivating the lipases by heat, after varied time intervals. The treated milk or cream was then used to standardize the skimmilk to the desired fat content. Numerous microbial and animal lipases and esterases were added to pasteurized whole milk, to develop varying degrees of rancidity, then inactivated by a heat treatment. Fatty acids, from acetic to oleic, were added individually and in combination to the cheese milk.

Additives. Buttermilk solids, fractionated butteroils, and monoglycerides, including monoolein, monoacetin, monostearin, glyceryl monostearate, acetylated monoglycerides (Mycovets;[1] Distillation Products Industries, Rochester, New York), and commercial monoglycerides (Myverols; Distillation Products Industries) were substituted in part for the milk fat in the cheese milk. Stabilizers, including cellulose gums, pectin, gelatin, carrageen, and starch, were tested for their effect on cheese body. Gamma lactones (C7–C12), methional, biacetyl, and sodium glutamate were added to cheese milk in attempts to improve cheese flavor. The effects of adding the following condiments on cheese flavor were determined: pimiento, hot pepper, onion, garlic, spices, and smoked salt.

Enzymes. In attempts to promote and hasten ripening, commercial proteases (Rhozymes; Rohm and Haas, Philadelphia, Pennsylvania) and crude microbial proteases prepared from cultures of *Streptococcus zymogenes* and *Streptococcus liquefaciens* were added to the cheese milk. In some instances they were allowed to act for a short time, then inactivated by heat. In other instances they were not inactivated.

Assessment of product and chemical analysis. The cheeses were examined organoleptically by laboratory staff members after intervals of 2 wk and one, two, and three months of curing at 4.4 C, and graded specifically for body, texture, and flavor. Numerical ratings from 1 to 10 were used to indicate a) degree of flavor, and b) extent of ripening and body breakdown. Numerical values less than 5 were below an acceptable level.

The cheeses were analyzed for fat, salt, and moisture at 1 wk and after one to two months of curing. Fat and moisture were determined by the Mojonnier methods, and salt by the A.O.A.C. method (2). The extent of proteolysis during cheese ripening and the effects of various making procedures on proteolysis were determined by measuring the increase of soluble nitrogen. Samples of cheese for total and soluble nitrogen determinations were prepared by the method of Vakaleris and Price (8). The sodium citrate solutions of cheeses were used to determine total nitrogen, and the acidified filtrates analyzed for soluble nitrogen. Nitrogen determinations were performed by the micro-Kjeldahl procedure.

[1] Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.

TABLE 1
Manufacturing procedures affecting properties of low-fat cheese[a]

Make procedure		Manufacturing acidity			Moisture	Cheese assessment (1 month)			
		Cutting TA	Draining TA	Cheese 21 hr pH	21 hr	Body & texture Score	Body & texture Comments	Flavor Score	Flavor Comments
Milk	Raw	.21	.25	5.38	58.5	6	Soft	7	Mild
past. 60 C for 5 min		.20	.24	5.5	57.5	6	Sl. rubbery	7	Mild
72 C for 15 sec		.21	.24	5.65	57.7	7	Soft	6	Mild, lacks
85 C for 15 sec		.195	.245	5.5	58.3	8	Very soft	5	Lacks
Fat *(%)*	3.61	.20	.24	5.4	57.6	3	Hard, leathery	4	Lacks
	4.85	.20	.235	5.35	59.3	5	Medium soft	5	Lacks
	6.77	.21	.24	5.55	58.4	6	Soft, smooth	7	Good
	8.99	.20	.23	5.55	58.9	7	V. soft, creamy	8	Very good
Starter *(%)*	1	.14	.155	6.0	62.4	8	V. soft, mushy	3	Wheyish
	4	.17	.195	5.55	59.0	7	Soft	6	Sl. wheyish
	6	.20	.24	5.35	57.8	7	Soft	7	Mild
	10	.235	.285	5.25	56.9	6	Medium soft	6	Sl. cheesy, acid
Ripening period *(hr)*	0	.15	.17	5.7	57.6	6	Soft	4	Sl. wheyish
	1	.21	.25	5.45	58.2	6	Soft	6	Mild, clean
	2	.25	.295	5.25	57.9	6	Soft	5	Tr. bitter, acid
Curd size *(mm)*	3.2	.205	.24	5.6	52.7	3	Very hard	4	Lacks
	6.4	.21	.245	5.4	55.5	4	Hard	4	Lacks
	12.8	.20	.235	5.55	57.3	6	Soft	6	Mild
Cooking temp *(C)*	35	.20	.245	5.5	60.3	7	Soft	4	Sl. wheyish
	37.7	.19	.24	5.5	58.4	6	Medium soft	6	Mild, clean
	40.5	.20	.24	5.38	56.1	5	Dry	5	Lacks
	43.2	.20	.23	5.4	55.2	5	Dry	4	Lacks
Wash water temp *(C)*	None	.20	.23	5.35	56.7	5	Sl. hard	4	Sl. acid
	0	.20	.23	5.7	63.4	8	Very soft	2	Wheyish
	10	.20	.23	5.6	60.6	8	Very soft	5	Sl. wheyish
	26.6	.20	.23	5.4	57.4	7	Soft	6	Mild
	37.7	.20	.23	5.3	56.2	5	Sl. dry	5	Acid
Salt *(%)*	1.4	.19	.235	5.65	58.6	6	Soft	2	V. acid, bitter
	1.7	.19	.235	5.6	57.3	6	Soft	4	Acid
	2.0	.19	.235	5.4	57.1	6	Soft	6	Mild
	2.5	.19	.235	5.5	56.2	6	Sl. dry	6	Mild
Total solids *(%)*	9.3	.195	.24	5.52	57.8	6	Soft	5	Acid
	10.4	.19	.235	5.55	58.9	6	Soft	6	Mild
	11.0	.19	.24	5.60	58.2	6	Soft	7	Mild, sl. cheesy

[a] Uniform manufacturing conditions were used to test each set of variables. Conditions were not necessarily the same from one set to another.

Rancidity or the total fatty acid content of the lipase-treated whole milk was measured by the method of Thomas et al. (7). The degree of rancidity is expressed as a numerical value.

The column chromatography procedure of Keeney (4) was used to determine the total and lower fatty acids in the cheese. Determinations were usually made when the cheese had been cured for one month.

The cheeses were examined periodically for their bacterial content, usually at 21 hr and at one and two months. Tomato juice agar (1), incubated at 30 and 45 C, was used to determine total numbers, LBS medium (B.B.L.) at 37 C for lactobacilli, and standard plate count agar (6) at 5 C for *Pseudomonas* and psychrophiles.

Results and Discussion

Results of initial attempts to develop an improved procedure for making skimmilk cheese soon revealed three basic requirements: a small amount of milk fat was essential for flavor development; a relatively high moisture content was required to promote the desired rate and extent of ripening; and acidity during manufacture had to be controlled within a definite range to obtain the desired body and prevent development of acid and bitter flavors. Effects of these and other factors on the properties of skimmilk cheese are shown in Table 1. The cheese scores shown in Table 1 indicate the effects of individual variables. No effort was made in manufacturing to adjust or compensate for undesirable conditions. Thus, the scores do not reflect the quality of cheeses that may be produced under optimum conditions.

The intensity of flavor and the degree of softness and smoothness of body appeared to be related directly to the percentage of milk fat in the cheese, particularly in cheeses containing from 3 to 10%. The milk fat also imparted a mellowness and flexibility to the curd and greatly increased its moisture-retaining property. Cheeses containing less than 5% of milk fat were usually criticized for being hard, tough, and lacking flavor. Cheeses made entirely from skimmilk had almost no flavor. These results showed definitely that the presence of some milk fat is required to obtain a ripened cheese of acceptable body, texture, and flavor. Consequently, a minimum of from 6 to 7% was selected to meet this requirement and a method developed for making low-fat cheese instead of fat-free cheese.

Other than the milk fat content, possibly the greatest factor affecting the body, texture, and flavor of low-fat cheese was its final moisture content. Almost every step in the making procedure had some influence on the percentage of moisture retained in the curd; however, the milk-processing treatment, curd size, period of stirring the curd, and rate and extent of cooking the curd had the greatest effects. Cheeses containing more than 60% moisture usually became soft or even mushy during curing and often developed a fruity or wheyish flavor. Cheeses containing less than 56% moisture were hard and rubbery (Table 1). The optimum moisture content ranged from 57 to 59%. A greater protein breakdown, as reflected by increases in soluble nitrogen, had been expected in the higher-moisture cheeses. However, no such effect was detected (Table 2).

The amount of acid developed during manufacture had a direct effect on the amount of soluble nitrogen present after curing for one month (Table 2) and on the body and flavor of the cheese. Cheeses that developed less than 0.18 titratable acidity (TA) prior to draining were usually wheyish or slightly unclean, and curdiness persisted for several weeks. Excessive acid development, more than 0.26 TA at draining, resulted in a rapid breakdown in protein, but the cheeses were usually acid or bitter. Acidity was best controlled by adding milk solids to the milk, adjusting the type and amount of starter, washing and cooling the curd, proper salting, and pressing the curd at a low temperature, as described previously (3).

Manufacturing procedure. Homogenization of the cream or whole milk used to standardize the skimmilk resulted in a definite improvement in the texture and smoothness of the cheese. It appeared to result in a slight flavor improvement, possibly by making the fat more accessible for enzyme action. A single stage homogenization, between 1,500 and 2,500 psi, was usually sufficient. The homogenization pressure within this range did not appear to be significant. However, when standardized milk was homogenized at pressures greater than 2,500 psi, short-bodied, inferior cheese resulted.

Cheeses made with raw milk or underpasteurized milk had slightly more flavor than those made from pasteurized milk. Processing the milk at higher than pasteurization temperature was effective in obtaining greater retention of moisture in the curd, but flavor was either lacking or undesirable in the cheese.

The solids content of the milk had a definite effect on the resultant cheese. Cheeses made from high-solids milk were less likely to become acid or bitter, possibly due to buffering action, and they had a slightly improved flavor. Milk fortified to 10.5–11% solids with nonfat

TABLE 2

Factors affecting cheese proteolysis—one month[a]

Treatment Variable	Range	Total nitrogen	Soluble nitrogen	Soluble nitrogen
		(mg/g)		*(as % of total)*
Starter inoculum	1%	4.34	.38	8.87
	4%	4.64	.51	10.88
	6%	4.21	.60	14.37
	10%	3.89	.65	16.71
Manufacturing acidity at dipping	.22	4.07	.34	8.3
	.23	4.365	.42	9.6
	.265	4.085	.425	10.4
	.30	3.895	.435	11.2
Milk-processing temperature, C	Raw	4.57	.58	12.80
	60–5′	4.26	.72	16.88
	72–15″	4.18	.61	14.59
	85–15″	4.27	.71	16.74
Moisture *(%)*	53.51	4.79	.57	12.07
	56.28	4.44	.53	12.09
	58.45	4.19	.54	12.93
	61.44	4.33	.55	12.86
Supplemental starters	None	4.34	.52	11.98
	V333	4.27	.51	11.94
	M572	4.35	.44	10.22
	Pseudomonas	4.19	.50	11.92
Enzymatic treatment	None	4.34	.52	11.98
	Active Rhozyme	4.46	.73	16.36
	Inactive Rhozyme	4.44	.82	18.42

[a] Uniform manufacturing conditions were used to test each variable.

dry milk was found to be optimum for making low-fat cheese.

Pretreatment of whole milk. Flavor in low-fat cheese made from fully pasteurized milk was improved by developmnet of mild rancidity. However, considerable difficulty was encountered in controlling the extent of rancidity when esterases or lipases were added directly to the milk. As the cheese aged, the rancidity usually became excessive and objectionable. Similarly, rancidity developed by microorganisms was difficult to control. Strains of *Pseudomonas fragi* usually imparted an undesirable fruity flavor.

Best development and control of flavor in the cheese was obtained when the small amount of milk fat used in cheese making was pretreated to activate the intrinsic milk lipases, and further lipolytic activity was stopped by heat. Degree of rancidity in the cheese was then easily controlled by regulating the amount of rancidity developed in the pretreatment procedure or by varying the amount of rancid milk fat used in cheese making. The desired flavor was usually obtained when raw whole milk was homogenized at 40 C, held for 1 hr, and the lipase inactivated by heating at 68 C for 5 min. This pretreated milk was then added to skimmilk in a ratio of approximately 1:5. Acid degree values for the pretreated whole milk usually ranged from 4 to 6. Greater values or longer holding periods prior to lipase inactivation produced cheeses frequently criticized for rancidity or soapiness.

Commercial pregastric esterases were effective in pretreating pasteurized whole milk to develop a definite degree of rancidity. However, cheeses made from these milks failed to score as high as those made from milk treated to activate the natural milk lipases.

The fatty acid content of the low-fat cheeses varied markedly with the type of milk treatment, as shown in Table 3. Cheeses containing large quantities of the higher fatty acids were usually rancid or soapy.

Starters. The amount and type of starter had a marked effect on cheese flavor and to a lesser degree on cheese body. Cheeses made with 2% or less starter usually had a wheyish off-flavor. To obtain the desired flavor and acidity, a 6% starter inoculum was selected. The amount of starter (inoculum) used or the amount of acid developed in the vat, or both, definitely influenced rate of ripening. Table 2 indicates greater cheese ripening with increases in starter. No difference in soluble nitrogen was found when different amounts of starter were used, provided the amount of acid produced in the vat was the same.

Starters containing large proportions of

TABLE 3

Fatty acid content of low-fat cheese as affected by milk treatment[a]

Treatment	Acid degree value of whole milk	μM of Fatty acid per 100 g cheese			Cheese flavor
		Acetic Acid	Butyric Acid	Higher acids	
Raw milk	.31	310.0	30.6	148.4	Bland
Past. 60 C for 5 min	.35	348.0	32.0	172.0	Bland
Past. 72 C for 15 sec	.36	380.0	56.0	202.3	Bland
Pseudomonas fragi	.....	448.0	12.2	611.0	Slight improvement
Micrococcus caseolyticus	.....	302.6	12.9	700.0	Slight improvement
Activation 44 C for 1 hr	5.37	281.2	174.0	863.2	Definite improvement
of milk 44 C for 2 hr	5.99	380.0	248.4	1,130.6	Definite improvement
lipase 10 C for 24 hr	8.06	683.2	340.2	2,072.4	Too rancid
Activation A-37.7 C for 4 hr	5.4	302.6	960.2	1,579.0	Soapy
of com- B-37.7 C for 4 hr mercial lipase	6.8	320.0	493.4	1,765.4	Soapy
Added monoglyceride	.....	208.0	13.0	1,726.0	Soapy
Added oleic acid	.....	484.0	29.0	1,444.0	Soapy
Added commercial lipase	.....	478.0	936.0	240.0	Developed soapiness after 1.5 months
Sharp commercial Cheddar cheese	.....	1,874.0	915.6	750.0	Acid and sl. fruity

[a] Cheese samples analyzed after one month of curing. Commercial Cheddar cheese was approximately 2 yr old. Uniform manufacturing conditions were used to test each variable.

either *Leuconostoc* or *S. diacetylactis* did not improve cheese quality. *S. cremoris* starters containing *Leuconostoc* consistently produced good cheese, whereas cheeses made with starters containing *S. lactis* or *S. diacetylactis* were scored down for acidity or bitterness.

pH of the cheeses made with *S. cremoris* could be controlled within pH values from 5.4 to 5.6 at 21 hr, whereas cheeses containing *S. lactis* were usually from pH 5.0 to 5.3.

A supplemental starter of *L. casei* (Strain V333) was very effective in imparting a pleasing biacetyl flavor that persisted throughout the three-month curing period. Other strains of *L. casei* were less effective. Most supplemental starters showed very little improvement in cheese flavor and appeared to have little effect in cheese ripening during one month of curing.

A ripening period of 1 to 1.5 hr was usually necessary to develop the desired acidity in the curd when a 6% starter inoculum was used. Longer ripening periods or larger inocula produced cheeses usually scored down for excessive acidity.

A titratable acidity (TA) of .21 at cutting and a draining acidity of .24 usually produced cheese with a pH of 5.4 at 21 hr. When the pH at 21 hr was less than 5.4, the cheeses usually became too acid during curing. To maintain the proper moisture retention in the curd, it was essential to develop most of the manufacturing acidity prior to cutting the curd and to have a relatively short interval between cutting the curd and draining the whey. When more than .28 TA had developed at draining, the curd was inclined to be stringy and elastic. Cutting with 12.7-mm knives prevented excessive shrinkage during cooking.

Rennet. Greater amounts of rennet than normally used in making Cheddar did not improve body breakdown, and many of the cheeses were criticized for inferior flavor. An optimum of 75 ml of rennet per 454 kg of milk was established. Adding the rennet to cold milk and holding it overnight also had no beneficial effect.

Cooking. As expected, variation of cooking temperatures was an effective means of controlling moisture. Temperatures less than 35 C did not permit sufficient expulsion of whey and resulted in wet, mushy cheese. Dry cheeses usually resulted when the cooking temperature exceeded 38 C, unless the curd was cooled rapidly with water. Temperatures as high as 47.7 were used without significantly reducing the bacterial flora of the curd during the relatively short time before draining the whey.

Cooling the curd. Control of acidity and moisture in the curd was best obtained by cooling the curd with water. Temperature of the wash water and degree of curd cooling had a direct effect on moisture retention; the cooler the wash water, the greater the moisture retention in the curd. Cooling to 26.6 C was an effective means of obtaining cheese with approximately 58% moisture.

Salting the curd. As might be expected, the salt content of the cheese had a definite effect on rate and extent of acid development. An

optimum of 2.2 and 2.4% salt in the finished cheese was indicated. Higher salt concentrations were objectionable to taste, and less than 2% resulted in acid or sour cheese. Salting the curd with dry salt was the most satisfactory means of obtaining the desired salt content.

Pressing the curd. Vacuum pressing for a short period was essential to obtain a close-bodied cheese. Best results were obtained when vacuum pressing was done about 30 to 45 min after hooping. The weighted cheese was placed in a vacuum chamber, and a vacuum of 63.5 to 66 cm of mercury held for 5 min. Longer holding periods increased moisture loss.

Greater control of acidity and moisture was obtained when the cheeses were pressed at 4.4 C, rather than at the conventional 24 to 26.6 C. Immediately after vacuum pressing, the cheeses were placed at 4.4 C and pressed with 11.4-kg weights per 2.3 kg of cheese.

Food additives and flavors. In general, cheeses made with food additives developed undesirable or off flavors. However, certain selected monoglycerides, buttermilk solids, and fractionated butteroils could be substituted in part for milk fat. Monoglycerides, namely monoolein and Myverol 18–40, added at the rate of one part/thousand of cheese milk produced excellent-bodied cheese when used in combination with a small amount of milk fat. The cheese had a distinct and slightly sharp flavor. Cheeses made from milk containing active lipases and added monoglycerides became very rancid during curing.

Sweet, freshly prepared churned buttermilk solids added to the milk at the rate of five parts/thousand definitely contributed to a soft-bodied cheese; however, all commercial powders tested gave a stale, undesirable flavor to the cheese. Freshly made powders did not cause this defect.

Gamma octalactone added to the cheese milk at the rate of 0.1–0.2 ml/454 kg of milk gave a pleasing buttery-like flavor to the cheese. The higher lactones, C10–C12, gave a coconut-like flavor.

The desired characteristic cheese flavor was not noticeably enhanced by addition of methional, sodium glutamate, or biacetyl to the cheese milk.

None of the stabilizers, cellulose gums, pectin, gelatin, or starch, improved cheese body, and many produced objectionable flavors.

Cheeses made with pimiento, hot pepper, or garlic were pleasing in flavor and of acceptable quality.

Addition of microbial or commercial proteases to the cheese milk caused bitterness in the ripened cheese. However, bitterness was controlled or eliminated when the enzymes were added to the milk at an optimum temperature (usually 40.5 C), allowed to act for a short time, then activated by heat. Rhozyme P11 gave the least amount of bitterness to the cheese. It was most effective when added to the skimmilk at the rate of 20 g/454 kg of milk, held at 40 C for 1 hr, and inactivated by pasteurizing the milk at 85 C for 15 sec. Cheeses made with Rhozyme P11 were usually scored as having a cheese-like flavor.

Results of this research, involving over 1,200 lots of experimental cheese, indicate that a low-fat cheese of acceptable body, texture, and flavor can be made. However, the data given in this paper indicate that many different combinations of manufacturing procedures may be used to obtain an acceptable cheese. The procedure reported previously (3) describes one of the many combinations of individual steps. The data and comments presented here show the nature and extent of effects resulting from variations in individual steps in the procedure.

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